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PRELIMINARY REPORT ON PTERERGATES IN POGONOMYRMEX CALIFORNICUS

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The phylogeny of castes among social insects has a recognized importance in the question of development of organic forms through continuous or saltatory variation. For the Formicidae the castes are already well established in the early Tertiary,[1] among the first fossil records of these insects, although in the primitive ancestral wasps neither the social habit nor the polymorphism of the female appears. Differentiation into soldier, worker, and fertile forms is also a long-standing condition with the termites, probably dating from the Cretaceous.

In discussing the origin of castes among ants, Wheeler has considered the bearing of the subapterous and apterous females (particularly in the genus *Monomorium*) on the problem of variation through mutation.[1] He concludes that although the sterile worker-females are now almost universally wingless, we should not believe that this micronotal wingless condition arose through mutants. Rather "this view of the castes, at least so far as their origin is concerned, cannot be maintained, because all the available evidence points to their being merely the surviving extremes of graduated and continuous series of forms, the annectant members of which have suffered phylogenetic suppression or extinction." For the termites Thompson and Snyder find few intermediate types, but trace a gradation of characteristics throughout the series of five castes (workers, soldiers, and three fertile forms), and find a further argument against mutational origins in the fact that the different castes are essentially constant both in occurrence and in structure.[2]

It is of interest, in connection with these views on the phylogenetic development of polymorphism, to find in typical worker ants some ontological evidence of early stages in the origin of castes—to find, in particular, that the embryonic vestiges of wings, discovered in workers of *Formica* by Dewitz,[3] do not invariably disappear with the passing of larval and

pupal stages, but occasionally persist to the adult state. Wheeler described four adult workers of this kind in 1905, naming them pterergates,[4] but such forms are apparently very uncommon. As far as I know, only six were on record before 1919. Since then, in addition to the ants discussed in the present note, Professor Wheeler has kindly sent me one pterergate taken in Nova Scotia, I have found one, taken by Blaisdell, in the collection of the California Academy of Sciences, and one in a nest of *Pogonomyrmex* in Pasadena.

The record of species and localities for these nine pterergates is as follows:[5]

Pogonomyrmex californicus subsp., taken by Blaisdell, 1885, Powai, California.
Cryptocerus aztecus, taken by Wheeler, 1900, Cuernavaca, Mexico.
Myrmica scabrinodis var. (3), taken by Wheeler, 1904, Bronxville, New York.
Lasius flavus, taken by Bondroit, 1910, Landelies, Belgium.
Leptothorax curvispinosus, 1911, Weymouth, Nova Scotia.
Myrmica scabrinodis, taken by Keys, 1913, Yelverton, England.
Pogonomyrmex californicus, taken by Shapley, 1920, Pasadena, California.

All of the above, except *Lasius*, are Myrmicine ants.

From a local nest of the red Californian Harvester, *Pogonomyrmex californicus* Buckley, I have taken during the last two years more than 1700 workers, nearly one-half of which have vestigial wings in various stages of development. A summary of observations on this unique nest is given in the following paragraphs. An analysis of the development of the wing venation is reserved for later publication.

TABLE I

NUMBERS AND RELATIVE FREQUENCY OF PTERERGATES

GROUP	DATE	PTERERGATES	NORMAL WORKERS	PERCENTAGE PTERERGATES
a	Prior to Nov. 11, 1919	13	11	54
b	Nov. 11, 1919, to June 1, 1920	89	87	51
c	June 6, 1920	266	324	45
d	June 8, 1920	56	100	36
e	Oct. 15, 1920	49	51	49
f	Oct. 19, 1920	87	159	35
g	Oct. 19, 1920	8	16	33
h	Oct. 24, 1920	172	249	41
	TOTAL	740	997	42.6

1. The occurrence during 1919 and the early months of 1920 of equal numbers of pterergates and normal workers suggested that Mendelian factors might be involved in the appearance of wing vestiges. The pterergates became relatively much less frequent, however, in June, 1920 (table 1), suggesting that the tendency to develop vestiges was less pronounced or entirely absent for the 1920 brood; but on October 15 the per-

centage of affected forms appears temporarily re-established, notwithstanding that 320 of the normal ants had been returned to the nest after the June collections. Among the ants taken October 18 and 24 were a number of callows with well-developed vestigial wings; this also indicates that the tendency to produce pterergates still exists.

2. There is no obvious external reason why this particular nest should show such frequent reversion to a remotely ancestral condition of the worker ant. The intermittent war with Argentine ants (*Iridomyrmex humilis Mayr*), which is apparently destined to end in the elimination of most of the native ants in the California valleys, is no more severe for the nest of pterergates than for many other nests of *Pogonomyrmex*. This nest, however, has access to very little wild barley and similar grasses, a common food of the species; on the other hand, it is exceptionally well provisioned with mixed grains from a nearby feed store whenever the Argentine ants permit the nest to be opened for normal harvesting activities.

3. A small colony of the same species, less than ten feet distant from the nest containing pterergates, yields workers indistinguishable from the normal ants of the affected nest, but no pterergates; in fact, an examination of several thousand individuals from some fifty other colonies of this species within a radius of two miles has shown only the one pterergate listed above.

4. In all details of thoracic structure—size, sculpture, pilosity—the pterergates are identical with normal ergates of this and neighboring nests. In excavating and guarding the nest, and in harvesting, the pterergates and the normal workers participate equally. Hence these abnormal ants are certainly workers rather than modified fertile forms, such as pseudogynes, microgynes, and β-females.

5. The seventeen young queens and two males, taken from the nest in June, 1920, appear to be normal in every way when compared with queens and males from other nests of the same species.

6. Grouping the pterergates roughly in order of the development of vestiges, we have the following enumeration:

With minute veinless wing-sacs, or with stubs of broken wings	385
With sacs from 0.5 to 1.0 mm. long and indistinct veining	219
With transparent, clearly veined winglets from 0.8 to 1.5 mm. long	132

The gradation of wing vestiges is, however, perfectly continuous, from small protuberances (without appendages) on the mesothoracic segment to the most developed winglets, with venation approaching that of the wing (6 mm. in length) of the mature queen. This continuity in structure may be significant for the problem of variation and the origin of castes.

7. Four ants from the affected nest have vestiges of both posterior and anterior wings—a phenomenon not heretofore recorded, as only anterior wings are represented in all other pterergates.

[1] Wheeler, W. M., These PROCEEDINGS, **3**, 1917 (109–117).
[2] Thompson, C. B., and Snyder, T. E., *Biol. Bull., Woods Hole, Mass.*, **36**, 1919 (115–132).
[3] Dewitz, *Zs. wiss. Zoöl., Leipzig*, **30**, 1878 (78–105).
[4] Wheeler, W. M., *Bull. Amer. Mus. Nat. Hist., New York*, **21**, 1905 (405–408).
[5] Shapley, H., *Psyche, Boston*, **27**, 1920 (72–74).

HYDROGEN ION CONCENTRATION OF THE CONTENTS OF THE SMALL INTESTINE

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Communicated by W. A. Noyes, October 8, 1920

The contents of the small intestine were removed by swallowing a tube 7 feet long so far down that the outer end was at the teeth and there were no loops or coiled portions in the stomach. The tube was of smooth rubber, 1.5 mm. internal diameter and 3.5 mm. external diameter, and hence stiff enough to keep from collapsing. A 6-gram iron sinker was attached to the lower end to assist in the introduction of the tube. The swallowing movements of the oesophagus acting on this sinker pulled the tube down. When the tube reached the pylorus, the subject reclined on his right side with hips elevated so that the sinker would pass through the pyloric sphincter. This passage was accomplished more easily on an empty stomach, in fact, in one subject who swallowed the tube after a meal, passage of the pylorus was not accomplished until about 4 hours had elapsed and repeated trials did not lessen the time required. On an empty stomach, passage was accomplished immediately in two subjects, as demonstrated by the fact that a darkly bile-stained fluid flowed out of the tube. Bile may be regurgitated into the stomach, but is then diluted with gastric juice and saliva. The tubes were kept down in two subjects for 5 days and 4 nights. The subjects ate their meals regularly, went to lectures, went swimming, automobile riding, slept soundly, and, in fact, the only inconvenience experienced was consciousness of the presence of the tube in the throat owing to its stiffness. To alleviate this annoyance they ate ice cream and bananas during the afternoon. The withdrawal of the tube with sinker attached caused no inconvenience. It required the tube about 5 days to descend to its full length and it was examined each day with the fluoroscope by Dr. F. S. Bissell, the antimony in the rubber casting a distinct shadow.

The tube was kept clean by forcing distilled water down it when not in use. Samples of intestinal contents could be obtained only when digested food was coming down from the stomach. At other times hardly a drop of fluid could be obtained. The H ion concentration of the individual

samples are without apparent significance, but the average figures for each day show the contents to become less acid as the tube descended farther. The average figure for the 1st day was $10^{-4.7}$, 2nd day 10^{-5}, 4th day $10^{-5.1}$, and 5th day $10^{-6.2}$. The intestinal contents, when incubated at body temperature with boiled egg-white, showed hardly any proteolytic action. Probably egg-white requires to be swollen by the acid in the stomach before rapid proteolysis can take place. Egg-white will swell also in alkali, but the intestinal contents were near the isoelectric point of egg albumin, at which least swelling occurs.

On taking a census of laboratory workers, I found they all considered the intestinal contents as being alkaline, and, in order to account for this erroneous impression, reviewed the literature since the days when physiologists, ignorant of the germ theory, tasted body fluids to see whether they were acid or alkaline. Von Helmont, in 1648, found that the taste changed from acid to salt on passing from the stomach to the intestine. After the discovery of indicators, Tiedemann and Gemlin, in 1826, found that the soda from the common bile duct unites with the acid chyme and makes it less acid. In 1891, Macfadyen, Nencki and Sieber, with the aid of a grant from the Elizabeth Thompson Science Fund, studied the outflow from a fistula in the ileum of a patient continuously for 6 months and found it always acid. It seems strange, therefore, that the popular notion is that the intestine is alkaline and I cannot account for this unless it is due to the fact that the secretions of the pancreas and the glands of Brunner and Lieberkuhn in the intestine are alkaline as shown by titration and with the hydrogen electrode. They are not sufficiently alkaline to neutralize the acid chyme.

My determinations were made with the hydrogen electrode and after 5 years' experience with biological fluids, I have begun to feel confident of determinations without the precaution of triplicate and quadruplicate samples. Palladium electrodes are attacked by acid of the stomach and sometimes of the duodenum. I use gold electrodes plated bright with iridium. By using a very concentrated solution of iridium chloride the plating can be done in about 2 minutes, and the electrode may be used longer without replating than when plated with platinum, and is easier to clean because it is bright. In non-viscous fluids the electrode must be entirely immersed in the sample, and the latter kept saturated with hydrogen gas by shaking. The presence of oxygen gives a low voltage to the hydrogen-calomel cell. In such cases the voltage rises after the shaking has ceased. The acidity of the intestine aids in the preservation of the antiscorbutic vitamine while it is being absorbed. Feeding of lactose changes the intestines of guinea pigs from alkaline to acid.

BLOOD CONCENTRATION CHANGES IN INFLUENZA

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Communicated by L. B. Mendel, October 22, 1920

From the pathological viewpoint influenza presents a striking similarity to the respiratory complications induced by the lethal war gases, chlorine, phosgene and chlorpicrin. In both conditions there are two features that stand out prominently, namely, pulmonary edema and a pneumonic process. In both, edema may be regarded as the response to an intense inflammatory reaction resulting in a loss of the normal protective mechanism of the upper respiratory tract, thus allowing bacterial invasion of the lung.

It has been shown by Underhill[1] and his associates that in acute poisoning by the lethal war gases edema of the lungs is accompanied by marked changes in the concentration of the blood, which, according to Underhill, is the chief factor contributing to death. Blood concentration means a failing circulation, an inefficient oxygen carrier, oxygen starvation of the tissues, fall of temperature, and finally suspension of vital activities.

During the recent epidemic an opportunity was afforded to study a series of cases of influenza in the New Haven Hospital through the cooperation of Dr. George Blumer and his staff. The investigation with these subjects enables us to state definitely *that in the fulminating cases of influenza there is a marked increase in the concentration of the blood resembling closely that observed in the acute stages of gas poisoning. Death invariably followed a marked increase in blood concentration. Again, of the cases that recovered in not a single instance was there evidence of a significant increase in blood concentration.*

Therefore it is quite apparent that both physiologically and pathologically there is a marked resemblance between influenza and war gas poisoning. Blood concentration in both conditions is an important factor in the cause of death. Blood concentration is incompatible with continued existence.

Under proper conditions, blood concentration changes in influenza may be followed by accurate hemoglobin estimations.

A method of treatment evolved for acute gas poisoning has been applied with success in a few cases of influenza. The method consists in the maintenance of blood concentration as near the normal level as possible by venesection and fluid introduction.

[1] Underhill, *The Lethal War Gases: Physiology and Experimental Treatment*, Yale University, 1920.

LUMINESCENCE AT HIGH TEMPERATURES

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Read before the Academy, November 20, 1920

It is the purpose of this note to announce the discovery of luminescence at temperatures above those at which ordinary phosphorescence disappears and fluorescence, excited by light, reaches extinction: in a word, roughly speaking, above the beginnings of a visible red heat.

Luminescence at these higher temperatures has probably remained unnoticed[1] because the usual source of excitation has been light and photo-excitation, as was observed by Lenard and Klatt[2] in their studies of the phosphorescent sulphides, generally ceases below 400° C. The experiments of Wiedemann and Schmidt[3] on the effect of temperature on the kathodo-luminescence of certain substances reached their upper limit at about the same temperature, not because the materials ceased to glow but on account of the softening of the glass of their vacuum tubes.

The main facts about this luminescence at high temperatures, the details concerning which will be given in a series of forthcoming papers, may be briefly stated as follows:

1. *The glow is produced by a new type of excitation*, i. e., by contact with the outer zone of the hydrogen flame; also in some instances by kathode bombardment and the action of X-rays.

2. *The effect is quite distinct from photo-luminescence*, from which it differs in the following respects:

(*a*) It is observable in many substances incapable of excitation by light; such as the oxides of calcium, zinc, magnesium, aluminum, silicon and zirconium; and in sulphides of calcium and zinc of such purity as to be non-phosphorescent.

(*b*) It is absent in some strongly fluorescent materials such as willemite and calcium tungstate.

(*c*) The addition of a trace of some activating substance, as in the production of the phosphorescent sulphides, is not necessary. Such an admixture sometimes modifies the color of the glow but more frequently prevents fluorescence altogether. Thus many of the Lenard and Klatt sulphides and the well-known, red glowing, cadmium phosphate of Andrews are inert under the excitation of the flame.

(*d*) Where photo-fluorescent substances are active, as in Sidot blende, Balmain's paint and several of the phosphorescent sulphides, the luminescence has an upper limit of temperature far above that at which photo-excitation ceases.

3. *Distinguishing features in relation to temperature radiation.*—The effect often occurs at temperatures far below the red heat. When superimposed upon the red heat it is readily distinguishable:

(*a*) *By its color*, which is more often green, blue or white than ruddy.

(*b*) *By its law of decay*, which is that of vanishing phosphorescence instead of the law of cooling.

(*c*) *By its spectrum*, which is a characteristic broad banded fluorescence spectrum often lacking altogether in the red. The bands of these spectra are made up of over-lapping components which form series with the usual uniform frequency intervals.

4. *Limits of Activity.*—The upper limiting temperature (or temperature of extinction) differs with various substances. It is, for example, about:

690° C. for calcium oxide,
740° C. for calcium sulphide,
940° C. for zinc oxide and pure zinc sulphide.

The lower limit also varies through a very wide range; e. g., from

52° C. for aluminum oxide to
568° C. for the blue-green band of zinc oxide.

These limiting temperatures are in some cases very sharply defined.

5. *Individual excitation of bands.*—The over-lapping bands of the spectrum are separately excited and each has its particular active range of temperatures. As these differ, color changes with temperature result. In some cases the temperature ranges do not over-lap, so that two or even three fluorescences follow one another as the temperature rises. Thus zirconium oxide shows a bluish white fluorescence between 76° C. and 372°, followed by deep red between 440° and 720°.

6. *Kathodo-luminescence at high temperatures.*—Many of the substances which exhibit flame excitation are also luminescent in the kathode tube, and sometimes we find the same bands brought out and the same upper temperature of extinction.

Thus calcium oxide becomes extinct at about 690°, whether excited by the hydrogen flame or by kathode bombardment.

Sometimes the two types of excitation give strikingly different appearances, as in the case of the synthetic ruby, which shows the same pale green band as other forms of aluminum oxide in the flame but the well known brilliant red in the vacuum tube. Our observations indicate that under kathodic action also the bands are independently excited and that bands of shorter wave-length have a higher temperature range: Thus the color shift towards violet with heating recorded by Crookes and later systematically studied by Wiedemann and Schmidt (*l. c.*) is confirmed and explained.

7. Excitation by means of X-rays at these temperatures has thus far been tried only with a few substances. It was found, however, that calcium oxide, calcium carbonate, sidot blende and some of the phosphorescent sulphides which are subject to flame excitation respond also

to X-rays at temperatures up to a dull red heat. There is usually color change as mentioned under (6) and a distinct maximum of brightness at some intermediate temperature.

[1] In this statement reference is to *established* cases of luminescence. Exception is made of the rather numerous instances in which radiation of an unusual character is *ascribed* to luminescence without actual demonstration of the fact. The present author more than once has made such assumptions and believes them likely to be verified.

[2] Lenard and Klatt, *Ann. Physik, Leipzig*, **15**, 1904 (425).

[3] Wiedemann and Schmidt, *Ibid.*, **56**, 1895 (218).

FUNCTIONAL REGULATIONS IN ANIMALS WITH COMPOSITE SPINAL CORDS

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Communicated by R. G. Harrison, October 7, 1920

In several recent series of experiments,[1] involving the transplantation of the forelimb in Amblystoma embryos, a number of points were brought out by the author bearing upon the question of the functional readjustment of the peripheral nervous system in response to the altered conditions. The cardinal points may be summarized as follows:

(1) When the limb is transplanted to an abnormal (heterotopic) position, there is a striking tendency for its innervation to be derived from the original limb level of the cord, and only when this is totally or in part accomplished, is the limb capable of movements which are well coördinated with those of the opposite intact appendage.

(2) Transplanted limbs which are not supplied by the normal limb nerves exhibit a degree of function which is directly correlated with the region of the spinal cord from which the nerves are derived. The motility of the appendage is more perfect when its nerves come from segments of the cord adjoining those which contribute the normal limb nerves.

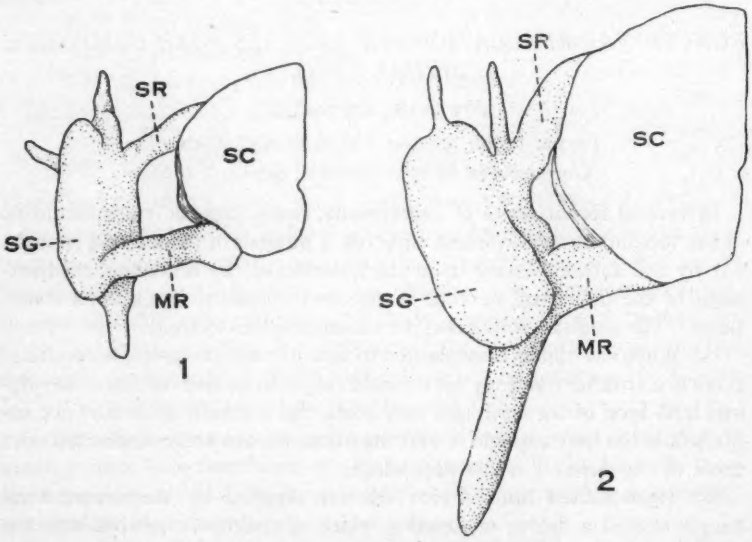
(3) The gradual loss of function as limbs are transplanted further and further away from the normal situation is attributed to increased defective connections within the central nervous system and not to a corresponding decrease in effective peripheral efferent innervation nor to deficiencies in in the skeleto-muscular mechanism of the limb and the shoulder girdle.

(4) Peripheral nerves supplying a transplanted limb are larger than their counterparts which have no connection with a limb. Critical examination has shown this enlargement to be due to a hyperplasia of the afferent neurones with no evident over-production of cells on the motor side.

The fact that structurally complete transplanted limbs with an adequate peripheral nervous mechanism, derived from the extra-limb level

of the cord, are capable of adaptive movements led to the inference above given, namely, that the defective motility is due to a corresponding inadequacy of central connections and not to any rigid specific relation between certain nerves and a given group of muscles. Further, the general failure of the motor centres to undergo hyperplastic regulation such as occurred in the sensory centres under the conditions of increased functional demands at the periphery, led to the view that factors other than the peripheral requirements must be sought for in the solution of motor readjustment.

In the light of these considerations, the experiments which are herewith



EXPLANATION OF FIGURES

(1) Reconstruction model showing the sensory (sr) and motor (mr) roots of the right eighth spinal nerve, the spinal ganglion (sg), and the corresponding level of the spinal cord (sc) × 180. Nerve not connected with limb. Case TrSc 137.

(2) Reconstruction model showing the enlarged senso-motor apparatus of the right fourth spinal nerve (originally eighth of another animal and transplanted into the limb level of the host) × 80. Nerve connected with limb, Case TrSc 137.

briefly reported were carried out. They consisted in removing that portion of the spinal cord from which the normal brachial plexus is derived (third, fourth and fifth segmental nerves) and transplanting into the excised area a more posterior portion of the spinal cord of another embryo that normally gives origin to the seventh, eighth and ninth segmental nerves. These latter nerves, in their normal position, are capable of producing but very limited movements when innervating transplanted limbs.[3] The limb rudiments were left intact.

In the present experiments the grafted unit of spinal cord, carrying with it the neuroblastic forerunners of the seventh, eighth and ninth peripheral nerves, is subjected to all the factors which normally produce the increased proliferation of nerve cells in the limb region, and the resultant degree of development of its neurone components under these conditions can be compared directly with the undisturbed seventh, eighth and ninth segments of the host.

The experiments were carried out on Amblystoma embryos ranging in age from those with completely closed medullary folds (stage 21) up to those with a prominent tail bud (stage 33), a stage just preceding that in which primary reactions first appear. Although the survival of the embryo appears to have no correlation with its age at the time of the operation, the percentage of normal results, both structural and functional, is clearly a function of the age of the embryo and the most normal results were obtained from embryos in the stage of closed neutral folds (table 1). The operated animals were reared in individual aquaria and the majority were kept under daily observations for from 60 to 75 days.

The effects of the transplantation upon the development of the embryo, the initial swimming reactions, and the functional behavior of the limbs are given in table 1. The bearing of these experiments upon the question of healing and regeneration of the spinal cord,[3] and upon the development of the primary swimming reflexes in the light of the work of Herrick and Coghill,[4] will be considered later.

The observations made on the living operated animals showed that the limbs in fifty per cent of the cases performed normal adaptive and coordinated movements (table 1). The movements of the remainder were partially impaired. The defects in these consisted mainly of (1) imperfect flexion of both arm and forearm, and (2) extensor paralysis of the wrist. Only two animals of the series have been sectioned thus far (cases TrSc 90 and TrSc 137), in both of which the limbs functioned normally. A microscopic study of sections from these animals showed the presence of a perfectly developed brachial plexus with normal intrinsic nerve distribution, derived from the grafted portion of the spinal cord (seventh, eighth and ninth segments). Not only were the transplanted segmental nerves found to be larger than the undisturbed seventh, eighth and ninth nerves of the host, with which they can be directly compared, but also the cord itself and the spinal ganglia showed distinct hyperplasia of the nerve cells (table 3, A2 and B2), thus indicating that the hypertropic development was due to excessive proliferation of the neuroblasts rather than to a compensating increase in the volume of a specific number of cell bodies and their axones.

The increased development of the motor and sensory contributions to the fourth nerve (originally the eighth) is shown in figure 2 and also in table 2. In the latter are given the weights and the weight ratios of unas-

TABLE 1

SHOWING THE EFFECTS OF REMOVAL OF THE FORELIMB LEVEL OF THE SPINAL CORD (3, 4 AND 5 SPINAL SEGMENTS) AND TRANSPLANTING INTO THE EXCAVATED AREA, A MORE POSTERIOR PORTION OF THE CORD (7, 8 AND 9 SPINAL SEGMENTS) FROM ANOTHER EMBRYO

STAGE OF DEV. WHEN OPERATION WAS PERFORMED	NO. OF OPERATIONS	POSITIVE EXPERIMENTS		NORMAL RESULTS		ABNORMAL RESULTS				AV. NO. OF DAYS AFTER OPERATION WHEN ABNORMALITIES WERE FIRST OBSERVED	AV. NO. OF DAYS AFTER OPERATION WHEN REACTION BEGAN	INITIAL REACTION				LIMBS WITH PERFECT FUNCTION		LIMBS WITH IMPERFECT FUNCTION		LIMBS WITHOUT FUNCTION		AV. NO. OF DAYS AFTER OPERATION WHEN LIMB REACTIONS BEGIN
						KYPHOSIS		LORDOSIS				PERFECT		IMPERFECT								
		CASES	%	CASES	%	CASES	%	CASES	%	DAYS	DAYS	CASES	%	CASES	%	CASES	%	CASES	%	CASES	%	DAYS
21–23	40	6	15	4	67	2	33	0	0.0	11	6	9	100	0	0.0							17
25–27	100	14	14	7	50	5	36	2	14	7–8	4	11	73	4	27	10	50	10	50	0	0.0	22
29–33	60	9	15	2	23	7	77	0	0.0	5–6	2–3	6	47	7	53							22–23
		29*																				

* Nine cases of the positive experiments were preserved before the period when limb reactions normally begin.

TABLE 2

SHOWING THE RELATIVE WEIGHTS OF THE SENSORY AND MOTOR COMPONENTS OF THE 4TH AND 8TH SEGMENTAL NERVES

(Weight of Model in Grams)

	SENSORY ROOT	MOTOR ROOT	SPINAL GANGLION	SPINAL CORD (140 SECTIONS)	
				TOTAL	CELL AREA
Fourth nerve* (connected with limb)...	1.3	4.3	14.5	209.6	97.3
Eighth nerve (not connected with limb....	0.3	1.1	5.1	121.5	50.9
Weight ratios.....	3.5	3.7	2.8	1.7	1.9

* The fourth nerve was developed from a transplanted portion of the spinal cord which normally gives rise to the eighth nerve.

TABLE 3

SHOWING THE NUMBER OF CELLS COUNTED IN (*a*) 10 CONSECUTIVE TRANSVERSE SECTIONS IN THE RIGHT HALF OF THE SPINAL CORD ANTERIOR TO THE EXIT OF THE 4TH AND 8TH NERVES, AND (*b*) IN THE 4TH AND THE 8TH RIGHT SPINAL GANGLIA

	CONDITIONS	LEVEL OF 4TH NERVE (CONNECTED WITH LIMB)	LEVEL OF 8TH NERVE (NOT CONNECTED WITH LIMB)	RATIOS
A	(1) Normal.....	1750	930	1.881
A	(2) 7, 8 and 9th spinal segments substituted for the 3, 4 and 5th..	1300	824	1.577
A	(3) Limb excised (spinal cord intact).....	1580	890	1.775
		4TH RT. SPINAL GANGLION	8TH RIGHT SPINAL GANGLION	
B	(1) Normal.....	1430	685	2.087
B	(2) As in A2.....	1860	945	1.968
B	(3) As in A3.....	685	720	0.951

sembled blotting paper models of the component parts of both fourth and eighth nerves, the former of which is in connection with the limb. Both motor and sensory roots of the fourth nerve (transplanted eighth) have undergone striking enlargement under the conditions which normally produce the increased proliferation of those centres in the limb region.

The hyperplastic development of the sensory centres, secondarily brought into connection with a transplanted limb, has been shown in recent experiments,[5] although no over-production of motor cells could be found. Under the conditions of the present experiments the nerve cells in the transplanted portion of the cord, which has been subjected to the factors normally producing the brachial enlargement, have undergone a degree of development, as indicated by a cell count, which almost equals that of the normal (table 3A, 1 and 2). The hyperplasia of the motor cells, however, under these conditions is evidently not the result of the functional activity of the limb with which the nerve is connected, for in the absence of the limb the production of cells in the limb level of the spinal cord is almost as great as under normal conditions (table 3A, 1 and 3).

The possibility that the ingrowth of the axones of a given number of peripheral afferent neurones might determine the extent to which the motor centres will develop, is negated by the facts obtained from previous limb experiments,[6] which show that a certain degree of both hypoplastic and hyperplastic development of the sensory neurones in a given reflex pathway can be induced experimentally without effecting a corresponding measure of development on the motor side.

The evidence thus far obtained indicates, therefore, that the factor which is involved in the over-production of the motor cells is the stimulus afforded by the connection with the central neurones (bulbo-spinal fibers), a large number of which very likely run only as far as the limb level where they discharge into the appendicular motor centres.

This preliminary report will be followed by a detailed account of the experiments, as well as a discussion of the results bearing more particularly upon the factors involved in the growth phase of nervous development.

[1] Detwiler, S. R., (*a*) These PROCEEDINGS, **5**, 1919 (324–331); (*b*) *Ibid.*, **6**, 1920 (96–101); (*c*) *J. Exp. Zoöl.*, **31**, 1920 (117–169).

[2] See 1 (*c*) pp. 142–147, series AS5 and AS6.

[3] An account of healing and regeneration of the spinal cord in frog embryos is given, by Hooker, D., in the following papers: (*a*) *J. Comp. Neur.*, **25**, 1915 (469–495); (*b*) **27**, 1917 (421–449).

[4] Herrick, C. J., and Coghill, G. E., "The Development of Reflex Mechanisms in Amblystoma," *J. Comp. Neur.*, **25**, 1915 (65–85).

[5] See 1 (*b*).

[6] See 1 (*b*), pp. 96–98.

EXPERIMENTS WITH THE TUBE RESISTANCE FURNACE ON THE EFFECT OF POTENTIAL DIFFERENCE

BY ARTHUR S. KING

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Communicated by George E. Hale, October 12, 1920

The form of electric furnace which has been found most effective in spectroscopic work is the tube resistance type, in which the substance to be vaporized is placed in a graphite tube heated by a current, the electrodes being applied at the ends of the tube. A column of vapor of almost uniform temperature is thus obtained in a considerable length of the tube. The temperature can be closely controlled and raised until the vaporization of the tube material becomes very violent, in the neighborhood of 3000° C. Regulated in this way, the furnace has uniformly emitted a definite spectrum of the enclosed vapor at a given temperature, and much evidence has been gathered which indicates a high degree of independence of chemical action arising from the use of various compounds or the presence of different gases in the furnace chamber, such actions appearing to affect the general intensity of a spectrum without materially modifying its character.

Since an important feature of the furnace is the excitation of the enclosed vapor by the high temperature of the tube rather than by the passage of a current as in the case of the arc, any approach to arc conditions which may result from the mass of ionized vapors being exposed to the potential difference of the ends of the tube must be carefully taken into account. It is obvious that a certain amount of such conduction may take place, in spite of the low potentials employed and the very small resistance of the graphite tube. Experiments have therefore been carried out to see whether, at least for the temperatures which usually bring out the important features of furnace spectra, a reduction or elimination of the potential difference by special means would cause any deviation from the spectrum observed at the same temperature with the regular operation of the furnace. For this purpose the tube was charged with iron, and certain lines very sensitive to change of temperature and especially strong in the arc were taken as a test spectrum. The bands given by the vaporization of the carbon tube and the lines of titanium and vanadium resulting from impurities were noted for the same purpose.

A reduction of the potential difference was obtained by two methods: first, by the use of direct current, which avoided the high momentary values of the alternating voltage usually employed; and, second, by using an insulated tube to contain the luminous vapor, inside the tube carrying the current, this inner tube furnishing an extra low-resistance path for any current not carried by the furnace tube. In each case, the test

spectrum was the same at a given temperature, showing no effect of the reduced possibility of conduction by the vapor. With the first method, an extra protection of the tube from loss of heat permitted the observation of the test spectrum with a potential difference of less than 0.6 volt per centimeter length of the tube.

Two experiments in which there was no potential difference on the tube were next tried. In one, the tube was heated, the current broken, and the exposure made during an interval while the tube cooled with no current. The spectrum was found to be the same as when the furnace was operated in the regular way at the mean temperature of the no-current experiment. In the other test, a tube containing iron was heated by a high-current arc between horizontal electrodes supported beneath the tube. The vapor in the tube used as a crucible in this way emitted a spectrum in which the test lines appeared as in the resistance tube carrying a current.

The conclusion from this series of experiments is that for the temperatures required in the line classification which the writer has carried out for a number of metallic spectra, the potential difference acting on the tube is not effective in modifying the spectrum, the lines sensitive to arc conditions appearing with equal ease whether a voltage is acting on the tube or not. Higher temperatures, accompanied by increase of both ionization and potential drop, should be checked when possible as to the effect of conduction by the vapor. Lines brought out only at these higher temperatures are, however, usually so faint that they are of little importance in the furnace spectrum. For a study involving these lines, the arc would usually be employed.

AN APPLICATION OF THE PORISM OF FOUR TANGENTS OF A TWISTED CUBIC

By J. H. McDonald

Department of Mathematics, University of California

Communicated by E. H. Moore, October 25, 1920

The problem of determining the involutions of degree n of a given discriminant has not been solved except when $n = 2,3,4$.

Special forms of discriminant occur in Jacobi's transformation of elliptic integrals and in researches on reducible integrals. Geometrically the problem is to construct a rational curve in n-space of degree n to touch $2(n-1)$ hyperplanes of a pencil. For $n = 3$ the solution depends on a certain porism;[1] that of four tangents of a twisted cubic. There is in fact the theorem: No proper twisted cubic can be drawn to touch four lines unless they satisfy a condition in which case an infinity of cubics

[1] Dixon, A. C., on twisted cubics which fulfil certain conditions, *Quar. J. Math.*, **23**, 1889 (343–357).

can be drawn. Let $abcd$ be four tangents to a twisted cubic meeting their transversals l and l' in $ABCD$, $A'B'C'D'$ and let AA', CC' touch the cubic at points of parameters o, ∞ and BB', DD' at points of parameters θ,φ. It is found that the equations of AA' are $x = y = 0$, of CC' $z = w = 0$, of BB' $x - 2\theta y + \theta^2 z = y - 2\theta z + \theta^2 w = 0$, of DD' $x - 2\varphi y + \varphi^2 z = y - 2\varphi z + \varphi^2 w = 0$. The equations of l are $x - \kappa y = 3z - \lambda w = 0$, of l' $x - \lambda y = 3z - kw = 0$, where k,λ are connected with θ,φ by the equations $\theta + \varphi = \kappa + \lambda/2$, $\theta\varphi = {}^1/_3\,\kappa/\lambda$. Putting $m = \{ABCD\}$, $n = \{A'B'C'D'\}$ the cross-ratios are connected by an equation. The values of m and n are

$$\frac{\varphi}{\theta}\cdot\frac{3\theta - 2\lambda}{3y - 2\lambda}, \quad \frac{\theta}{\varphi}\cdot\frac{3\theta - 2\kappa}{3\varphi - 2\kappa};$$

if $\theta/\varphi = t$ it is found that $mn = t^4$, $m + n = t^4 + 1 - (t-1)^4$.

Eliminating t; $m^{1/2} - n^{1/2} = 2m^{1/4}n^{1/4}(1 - m^{1/4}n^{1/4})$. This is the poristic condition or if the ranges on the transversals of four lines satisfy this condition an infinity of cubics can be drawn to touch them. The modular equation for the cubic transformation appears here.

To determine the involutions of cubic forms of a given discriminant, let $\alpha\beta\gamma\delta$ be four planes of a pencil of axis l; in $\alpha\beta\gamma$ take lines abc arbitrarily (distinct from l) meeting l in distinct points ABC. The cubics tangent to abc and the plane δ are of multiplicity ∞^2 being subject to 10 conditions. Let d be the line in δ tangent to a cubic and D its intersection with l and l' the second transversal of $abcd$. If m n have the same meaning as before n is given being the cross-ratio of the pencil $\alpha\beta\gamma\delta$ and m has four values. D has four positions and the lines d form four pencils.

To see that to a value of n correspond only four values of m it suffices to notice that the equation between m and n results from the elimination of t between $mn = t^4$, $m + n = t^4 + 1 - (t-1)^4$. Considering n as given and eliminating m there results an equation of degree four for t and so four values of m are found.

The final result may be stated in this way. Let $ABCD$ be any four points on the axis of a pencil of planes $\alpha\beta\gamma\delta$ and suppose $\{ABCD\}\{\alpha\beta\gamma\delta\}$ connected by the modular equation; then any four lines, one through each point to lie in the corresponding plane, are tangent to an infinity of twisted cubics.

There are four inequivalent involutions determined on these cubics by the pencil of planes, and n is the invariant of their discriminant. Their construction is as follows: Given n, determine m by the modular equation. From $\theta + \varphi = {}^1/_2(\kappa + \lambda)$, $\theta\varphi = {}^1/_3\kappa\lambda$ and

$$m = \frac{\theta}{\varphi}\cdot\frac{3\theta - 2\lambda}{3\varphi - 2\lambda}$$

$\kappa\lambda$ are determined uniquely. For $mn = t^4$, $m + n = t^4 + 1 - (t-1)^4$

regarded as equations in t have a unique common solution, φ may be arbitrarily taken and $\theta = t\varphi$. The equations of l are $x - \kappa y = 3z - \lambda w = 0$ and the cubic is $x = \sigma^3$, $y = \sigma^2$, $z = \sigma$, $w = 1$; or finally the involution is $\sigma^3 - \kappa\sigma^2 + \mu(3\sigma - \lambda)$ a single one determined by each value of m.

Putting $X = x - \kappa y$, $Y = x - \lambda y$, $Z = 3z - \lambda w$, $W = 3z - \kappa w$ the planes $X = 0$, $Y = 0$, $Z = 0$, $W = 0$ are the faces of the tetrahedron whose edges are a, c, l, l'. The collineations ($X' = \rho_1 X$, $Y' = \rho_2 Y$, $Z' = \rho_1 Z$, $W' = \rho_2 W$) leave invariant the lines $abcdll'$ evidently but transform any cubic tangent to $abcd$ into an infinity of others.

The coincidence of the equation between m and n with the modular equation leads to this geometrical theorem. If four planes of a pencil of axis l touch a cubic and the tangents meet l in $ABCD$ and if the planes meet the cubic in simple intersections $A'B'C'D'$ then $\{A'B'C'D'\} = \{ABCD\}$.

STUDIES ON THE TRANSFORMATION OF THE INTESTINAL FLORA, WITH SPECIAL REFERENCE TO THE IMPLANTATION OF BACILLUS ACIDOPHILUS, II. FEEDING EXPERIMENTS ON MAN

BY HARRY A. CHEPLIN AND LEO F. RETTGER

BACTERIOLOGICAL LABORATORY, YALE UNIVERSITY

Communicated by L. B. Mendel, October 20, 1920

In a recent communication in these PROCEEDINGS 6, 1920, pp. 423–426 the results of feeding experiments with albino rats were presented. Similar attempts to implant *Bacillus acidophilus* in man have led to the following conclusions.

Thorough implantation may be effected by the daily administration of 300–400 grams of lactose, 300 cubic centimeters of a whey broth culture of *B. acidophilus* (McFarland nephelometer turbidity scale of 5), or by a combination of 150 grams of lactose and 150 cc. of the whey broth culture. Complete transformation of bacterial types may be brought about also by the daily use of 500–1000 cc. of acidophilus milk culture.

The same results are obtained with dextrin as with lactose, but dextrose, sucrose and maltose exert no flora-transforming influence.

The time required for changing the flora varies with the nature and the amounts of the material administered. The most rapid implantation was obtained with the *Bacillus adophilus* milk. In two of the subjects 500 cc. of the milk brought about marked alteration within two to three days. Some of the subjects that were but slightly affected by 500 cc. of the milk culture showed very pronounced transformation when 100 grams of lactose were added daily to this amount.

No change could be detected in the hydrogen ion concentration of the

feces during the experimental periods. The transformation of the intestinal flora from the usual mixed to the simple aciduric type cannot be ascribed, therefore, to increased acidity within the lumen of the intestine.

The presence of a reducing substance in the feces of subjects receiving transforming amounts of lactose is further evidence in support of the view that the lactose is at least in part carried into the large intestine and helps to create in it an optimum environment for the development of *B. acidophilus*.

Attempts to implant *Bacillus bulgaricus* in the intestine of man failed in every instance. The conclusions arrived at in the rat feeding experiments are borne out here.

Seventeen human subjects were employed in a total of 45 experiments. All but two of these subjects were apparently normal individuals. No restrictions were made in the daily diets, which continued essentially the same as before the investigation.

B. acidophilus milk possesses several advantages over ordinary sour and *B. bulgaricus* milk, aside from its property of transforming the intestinal flora. It is pleasing to the taste and smell. It does not become very acid or in any other way materially change its character even on long standing. The curd is soft and of a creamy consistency. The creamy appearance of the milk persists without appreciable wheying off. The product is prepared easily when proper precautions are taken. Pure strains of *B. acidophilus* must be employed which have been grown in milk sufficiently long to produce acidity and a soft curd within 24 hours when kept at a temperature of 35–37° C.

The same methods were employed in the routine examination of the feces as in the earlier experiments with rats, namely, the preparation and use of whey agar plates, Veillon tubes and Gram-stained slides. The plates and the Veillon tubes were particularly valuable and are strongly commended for work of this kind. The Veillon tubes aided not only in the detection of *B. acidophilus* colonies, but served admirably as an index of the disappearance of *B. coli* and other gas-producing bacteria from the intestine. It soon became evident that as the aciduric type of organisms materially increased in numbers the volume of gas in the tubes correspondingly decreased. A so-called complete transformation of flora was evidenced by the crowding of the whey agar plates with small fluffy colonies, the absence of gas from the Veillon tubes, as well as complete preponderance of the characteristic sea-urchin-like colonies throughout the tubes, and by the large numbers of Gram-positive rod-shaped organisms of the *B. acidophilus* type on the stained slides.

A full account of the authors' studies on the transformation of intestinal flora and the implantation of *Bacillus acidophilus* is now in the Yale University Press, and will appear in book form at an early date.

THE KILAUEA VOLCANO OBSERVATORY

BY A COMMITTEE OF THE NATIONAL ACADEMY OF SCIENCES

PREPARED AT THE REQUEST OF THE SECRETARY OF AGRICULTURE

Communicated by C. D. Walcott, October 8, 1920

February 11, 1920.

DR. CHARLES D. WALCOTT, *President*,
The National Academy of Sciences.

DEAR SIR:

The Committee appointed by you to respond to a request from the Secretary of Agriculture for the advice of the National Academy of Sciences in regard to the conduct, by the Weather Bureau, of the Kilauea Volcano Observatory on the island of Hawaii, submits the following report. This Committee consists of Whitman Cross, Chairman, William Bowie, Arthur L. Day, Herbert E. Gregory, and Harry Fielding Reid. The letter of the Secretary of Agriculture indicating the scope of the subject on which the assistance of the Academy is desired is as follows:

DEPARTMENT OF AGRICULTURE, WASHINGTON,
January 18, 1919.

DR. CHARLES D. WALCOTT, *President*,
National Academy of Sciences,
Washington, D. C.

DEAR DOCTOR WALCOTT:

May I not request the National Academy of Sciences to give the Department the benefit of its advice with reference to scientific questions involved in the conduct of investigations in seismology and volcanology, to be carried on principally at the Kilauea Volcano, Hawaii, and elsewhere as the circumstances may warrant? The Congress, at its last session, appropriated $10,000 for this purpose, and it apparently had in mind the transfer to Government support and direction of the investigations now under way at this volcano, under the supervision of Dr. T. A. Jaggar, which are supported by the Hawaiian Volcano Research Association. The Department, through the Weather Bureau, desires to inaugurate the work promptly and efficiently and to secure the best contributions to the science of volcanic and seismic actions that may be possible within the limited appropriation available. If the representatives of the Academy of Sciences designated to consider this problem desire further details relative to the questions involved, the Chief of the Weather Bureau will be very glad to coöperate with them in every feasible way. I shall appreciate it if you will give the matter your early and favorable consideration.

Very truly yours,

D. F. HOUSTON, *Secretary*.

Soon after the appointment of the Committee it secured from Prof. C. F. Marvin, Chief of the Weather Bureau, a full statement in regard to the work of the Kilauea Observatory and the circumstances of its transfer from the Hawaiian Volcano Research Association. The Committee is much indebted to Professor Marvin for his cordial coöperation at all times.

The request of the Secretary of Agriculture pertains on the one hand to the immediate conduct of the Kilauea Observatory under existing appropriations, and on the other to the general subject of investigations in seismology and volcanology under the auspices of the Weather Bureau which may be conducted elsewhere than at Kilauea if circumstances warrant. As prompt action was desirable regarding the observatory, while the broader subject required further consideration, the Committee submitted to you under date of February 12, 1919, a preliminary report with recommendation as follows:

> The Committee recognizes the importance of the work hitherto accomplished at the Kilauea Observatory under the auspices of the Hawaiian Volcano Research Association and the direction of Dr. T. A. Jaggar, Jr. It also recognizes the great importance of maintaining continuity in the observations and records of the Observatory. This continuity appears to be endangered and the Committee earnestly recommends that the Department of Agriculture, through the Weather Bureau, should immediately take control of the Hawaiian Volcano Research Association equipment and provide for the uninterrupted continuance of the present program of observations and records until opportunity has been given for a thorough study of the opportunities for research in volcanism and seismology in this and adjacent regions, and the possible agencies through which a concordant and effective program can be carried out. The agreement already reached between the Department and the Hawaiian Volcano Research Association appears to furnish an appropriate basis upon which the Weather Bureau can assume control of the Kilauea Observatory.
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> The broad request of the Secretary of Agriculture for advice as to the scientific problems involved in the conduct of the work in question, in order to secure the best results possible under the available appropriation by Congress, requires more mature consideration on the part of the Committee. It will give careful attention to this matter and submit its full report as soon as possible.

This report was transmitted by you to the Secretary of Agriculture, and in accordance with its recommendation the control of the Kilauea Observatory was at once assumed by the Weather Bureau and has been maintained under the general plan of its earlier administration. The Committee now presents its complete report and recommendation on the subjects outlined in the Secretary's letter to you, giving particular attention to the broader aspects of researches in seismology and volcanology and the larger agencies devoted to promoting them.

I. *Scientific Questions Involved in the Conduct of Investigations in Seismology and Volcanology.*—Seismology is the science of the causes and effects of earthquakes and the phenomena of their occurrence. Volcanology deals with the causes and phenomena of volcanic action and the character of the volcano itself. Both sciences treat phenomena arising from disturbances of more or less deep-seated origin in the lithosphere of the earth and are fundamentally branches of physical geology. Both belong to the group of the earth sciences, all of which are more or less intimately connected.

In seismology the immediate subject of investigation is the shock, heavy or light, which is transmitted from its sources through rocks to

the place of observation on the earth's surface. The propagation of this wave-like movement is a matter for physical and mathematical discussion but the shock must also be studied in regard to its origin, the geological conditions under which it arises, the character of the material through which it is transmitted, and the conditions under which divers catastrophic phenomena may be exhibited at the surface.

Nearly all earthquake shocks are known to be due to relief or strain in the rocks of the earth at various depths below the surface. Such relief sometimes occurs in fault zones in the rocks where the geologist has recognized that movements have also taken place in past epochs. Other earthquakes are associated with volcanic disturbances. The source of many earth tremors cannot at present be determined.

Volcanology deals most directly with the physical and chemical phenomena of activity at the vent. However, a volcano represents but one local, though important, phase of eruptive activity. Its lavas are often but a small part of the igneous matter involved in the movement, other portions consolidating beneath the surface or pouring out from fissures as lava floods which may not be demonstrably connected with a typical volcanic centre. Volcanoes are of many types of activity dependent upon the chemical character of the magma involved, including the associated gases, and on differing physical conditions. A volcano is a natural laboratory where the geologists, physicists, chemists, mineralogists, petrographers, seismologists, and other specialists have a most important opportunity to study a great many processes in operation which have been active during the entire history of the earth from the time of its oldest known rocks. The geologist is vitally interested in volcanic phenomena as he is in all current processes whose effects are visible, though perhaps not clearly comprehensible, in the older rocks. The study of extinct and more or less deeply dissected volcanoes of past ages and the theoretical discussions of igneous earth history point to various phases of volcanic activity as of particular importance. This information has an important bearing on the plan of investigation to be carried out at a volcano observatory.

The consideration of physical processes in special relation to the development of the earth is now commonly called geophysics. By analogy we may also recognize geochemistry. Volcanology is sometimes referred to as a branch of geophysics but it clearly bears an equally intimate relation to geochemistry. The prolonged physical and chemical processes of volcanism result, on the material side, in volcanic rocks, minerals, and the volcano itself. No scheme of volcanological research is complete which does not provide for supplementing the field observations by studies in physical, chemical, and petrological laboratories.

This brief and imperfect summary of the scope and relations of seismology and volcanology is designed to show that the "scientific problems

involved in the conduct of investigations" in these fields are many and complex. The coöperation of geologists, physicists, chemists, geodesists, and other specialists with volcanologists and seismologists is necessary both in constructing a plan for such research and in carrying it out.

In the abstract it is plain, we believe, that a general scheme of investigation in either seismology or volcanology is distinctly beyond the proper scope of the Weather Bureau's activities. This Committee cannot recommend that the Weather Bureau should organize special departments of research in these sciences. But there are conditions at the present time which make it both appropriate and fortunate that the Weather Bureau should assume the conduct of observation at the Kilauea Observatory. These modifying conditions will now be reviewed.

From the beginning of human history earthquakes and volcanic eruptions with their associated tidal waves have been perhaps the most awe-inspiring and terribly devastating manifestations of natural forces. They have occurred at irregular intervals, unexpectedly as a rule, and in widely separated parts of the world. Owing to long prevailing ignorance or crude ideas as to the causes of these phenomena, and to the difficulties in the way of making extended scientific observations concerning them, the sciences of seismology and volcanology are still in a poorly developed state. Science is as yet unable to predict where or when the next great catastrophic exhibition of either earthquake or volcanic activity may be experienced. Our present knowledge is sufficient, however, to show that, as our understanding of the source, the cause, and the nature of these phenomena increases, we shall gain in some measure a power to anticipate violent earthquakes and volcanic eruptions and to guard more and more successfully against their destructive and terrifying results.

It is essential to the future advance of seismology and volcanology that provision should be made to secure extensive and accurate observations and record of the phenomena involved. Studies of this kind must be carried on at the most favorable centres for such work, and according to plans of investigation representing the best information of the time. The extent and complexity of the work requires that it should be under the direction of an organization planned for the purpose. As the earthquakes or volcanic eruptions of to-day may be in the United States, Italy and Japan, those of to-morrow in New Zealand, Africa, or Iceland, and equally scattered at other times, it is plain that the researches in various countries, whatever their auspices, should be conducted on the same general plan, and that a world-wide correlation of data and coöperation in effort is of the greatest importance. In the closing paragraphs of this report is a statement of the reorganization now in progress, of international agencies intended to promote such coöperation.

The development of delicate automatic registering instruments for measuring the intensity and periodicity of earth tremors and analyzing

these complex motions into several components, has now progressed so far that a number of recording seismologic stations have been established in the United States by various government bureaus, in educational institutions and in private laboratories. In order that the records of such stations should be of much real value it is necessary, however, that certain conditions should be met. The sites must be selected with good judgment, the instruments should be of the best type, their installation must be satisfactory, and they must be in charge of skilled observers. Further, the efficiency of the seismologic stations in this country would be increased if they were under the supervision of a central coördinating organization. Such an organization does not exist, as yet. It would require, moreover, large financial support to establish the desirable number of special seismologic stations, with observers and adequate equipment, at all desirable points. The stations of the Weather Bureau are widely distributed, at many of them are trained observers capable of caring for seismometers and allied instruments, and it is, therefore, fortunate that Congress has for several years past appropriated a small sum of money which the Weather Bureau is authorized to spend in seismologic work.

It is the opinion of this Committee that, until a permanent special organization is created, the seismologic investigations of the Weather Bureau should be extended by the equipment of additional selected meteorologic stations, with the proper seismometers and other necessary instruments, to be operated by the staff of the Weather Bureau. The Committee, however, believes that the seismologic research of the Weather Bureau, if thus expanded, should be placed under the immediate direction of a trained seismologist, belonging to its corps. If this is inexpedient, it is suggested that the desirable supervision and advice might be secured by coöperation with the American Geophysical Union, connected with the National Research Council. It is to be noted that the Chief of the Weather Bureau and several of its staff are members of this Union, which includes also several of the leading seismologists of the country.

II. *Investigations in Volcanology and Seismology by the Weather Bureau in the Hawaiian Islands.*—Bearing in mind the general considerations as to researches in seismology and volcanology presented in the earlier part of this report, the Committee has reviewed the exceptionally favorable opportunity for obtaining valuable contributions to these sciences in Hawaii through the administration of the Kilauea Volcano Observatory and other studies of volcanic action by the Weather Bureau. The broader relations of such investigations have been considered. It is evident that the supervision of this work should be directed with due regard to general, provincial, and local relations which may now be discussed.

Observations and researches in volcanology and seismology carried

out at the Kilauea or any corresponding observatory cannot have their maximum value unless conducted with due appreciation of the more pressing problems requiring solution at the present time and of the work being done in other parts of the world to advance these earth sciences. Upon this basis the work in Hawaii can be most effectively directed, undesirable duplication avoided, and possibilities of fruitful coöperation recognized.

The Hawaiian Islands are one of many elongated groups or chains of volcanic islands scattered through the great Pacific Ocean basin. These islands have all been built up from considerable, and in some cases from great, depths, and some rise to notable heights above the sea. The Hawaiian chain really extends from the island of Hawaii for 1,500 miles to the west northwest far beyond the largest and best-known members of the group. The only active vents of the present time are the volcanoes of Mauna Loa and Kilauea on the island of Hawaii, but minor eruptions have occurred in geologically recent time on all of the principal islands, while submarine disturbances have been noted on the southeast of Hawaii which are supposed to indicate the existence of other vents where new volcanic mountains are being built up.

Kilauea and Mauna Loa are typical volcanoes of the sort formed by repeated eruptions of basaltic lavas, similar to those which have been predominant in the principal eruptions throughout the group and in most other islands of the Pacific Ocean basin. Kilauea, being one of the most frequently active volcanoes in the world, readily accessible, and presenting unusually favorable conditions for study, was naturally chosen as the site of an observatory of volcanic phenomena by the Hawaiian Volcano Research Association, formed by residents of the islands and assisted for a time by research funds donated by the Massachusetts Institute of Technology.

The work of the observatory, organized and directed to the present time by Dr. T. A. Jaggar, Jr., has already resulted in a most important contribution of fundamental data on the phenomena of volcanism, greater, perhaps, than has been obtained by the study of any other volcano. The value of systematic and continuous observation and permanent record has been clearly established. For example, it is only by such sustained and complete records that the facts of periodicity can be determined and an ultimate knowledge of the influences controlling such periodicity may be gained.

The Committee believes that the Weather Bureau can most effectively contribute to the advancement of the sciences of volcanology and seismology, under the present small appropriation, by maintaining the Kilauea Observatory as the major undertaking, with such extension of the work in lines to be suggested, as may be found practicable. The observatory should be regarded, however, as the chief base for researches

and observations on all active phases of Hawaiian volcanism, and not for Kilauea alone.

The work at Kilauea involves on the one hand the observation and record of phenomena and on the other certain investigations by the observatory staff or by specialists whose assistance it is practicable to secure. The researches as to gases associated with the magma at eruption and the development of heat through chemical reactions occurring under decrease of pressure and other conditions of approach to the surface are of greatest importance. The results of coöperation in these studies with investigators from the Geophysical Laboratory of the Carnegie Institution of Washington, already secured, illustrate the desirability of continuing such collaboration and promoting similar work in other lines. We understand this to be the commendable policy of the Director of the Observatory.

It is known that there have been marked differences in the chemical composition of the lavas erupted at various times in several of the Hawaiian volcanoes. It is very desirable to know the chemical composition of the magma exhibiting the observed characteristics of eruption and to note the relation of this composition to a great variety of textural and mineral features of the rocks developed on consolidation of the lava. It will be fortunate if the assistance of specialists capable of conducting such researches can be secured by coöperation or otherwise.

Mauna Loa, the giant volcano adjacent to Kilauea, presents many important problems for investigation, both individual and in relation to Kilauea. It represents a different stage in the development of a basaltic volcano. Its eruptions are on a larger scale than those of Kilauea and under somewhat different conditions. It is desirable to compare its phenomena with those of Kilauea, and to determine the genetic and existing connections of these two neighboring vents of similar magmas.

The difficulties of access to the summit crater of Mauna Loa and to the main rift or fault zones on which modern eruptions are most frequent make the investigations highly difficult or impossible at this time. The Committee recommends that special attention be given to the development of trails, the establishment of shelters and camps, and the provision of proper equipment, which will facilitate access to the most important points for observation. It is desirable to establish a systematic investigation of Mauna Loa as soon as possible. It will be impracticable, naturally, to subject this enormous volcano to such constant observation as is feasible at the comparatively diminutive Kilauea, but adequate preparation will permit the securing of very important supplementary or confirmatory data from study of the short-lived but often extensive eruptions of Mauna Loa.

It is to be hoped that this work may be promoted through coöperation of the National Parks Bureau, the Hawaiian Volcano Research Association and other agencies interested in the study of Mauna Loa.

Besides the study of the active volcanoes it is recommended that the Weather Bureau should include in its field of observation all minor phenomena, such as fumaroles, steam vents, hot springs, local seismic shocks, etc., which indicate either the dying out or renewal of volcanic action at other places. A complete record of such activities in all islands of the Hawaiian group should be kept and observations made from time to time. Thus it is reported that fumaroles exist on the southern slopes of Haleakala, the great volcano of eastern Maui, at points not readily accessible. The evidences of relatively very recent eruptions within the crater of Haleakala and the existence of these fumaroles show that the volcanic fires cannot be assumed to be quite extinct, and may possibly flare up at any time. Facilities should be provided for visiting all places where traces of subterranean heat are found.

Seismologic work at Kilauea, or in the immediate vicinity of any active volcano, is mainly an adjunct to the study of that volcano, and it is a part of the work deserving of careful attention. It will also throw light on the nature of so-called "volcanic earthquakes." By adequate instrumental record of shocks originating in the volcanic field it is certain that valuable information of increasing or declining activity may be obtained which will be an important factor in forecasting future eruptions. This would be of special importance as regards eruptions of Mauna Loa. It will be necessary, however, to place seismographs adapted to this work at several places about the mountain in order to locate approximately the point at which an outbreak may be anticipated. If a relatively cheap instrument which can be attended to by a volunteer observer becomes available, this observation of local shocks originating beneath Mauna Loa should be provided for.

The seismographs hitherto in use at the Kilauea Observatory are not of the best models obtainable at the present time. Some of them have been loaned by private institutions or individuals. It is, of course, highly desirable that the observatory should be equipped with its own instruments, of types best suited to the purpose.

The Kilauea Observatory is, manifestly, not the most favorable site for seismometers designed to record earth tremors originating in other parts of the Hawaiian Islands or at still more distant sources. For such instruments an installation at the island of Oahu would be much more suitable. If a study of the seismic disturbances of the Hawaiian group as a whole is to be carried out, it would be necessary to establish secondary stations with appropriate instruments, at selected points on other islands of the group.

III. *General Conditions Affecting Future Direction of Work by the Weather Bureau.*—It was pointed out in Part I of this report that the advancement of volcanology and seismology, especially in the fundamentally important matter of accurate observation of phenomena, would

be greatly promoted by systematic coöperation of scientific men of all parts of the world, working at the presumably widely scattered centres of either volcanic or earthquake activity which may be of special importance at any given time. Efforts to establish such coöperative researches in various earth sciences are now being made. The field to be covered is so great that in some places laboratories or observatories are likely to be established where work in several directions can be carried on. As an instance may be cited the observatory at Apia, in Samoa, founded by the Göttingen Academy of Sciences, where data of much value in the fields of seismology, meteorology, terrestrial magnetism, atmospheric electricity and tidal movements have been obtained.

While this committee believes that the Weather Bureau should not undertake to organize an extensive scheme of investigation in volcanology, it is felt that it may well conduct the work of the Kilauea Observatory for the present. It may be pointed out in this connection that meteorological observations of much value to the Weather Bureau are made under the auspices of many private institutions and individuals, as a contribution to the work of the Bureau..

In the course of the development of scientific research it may well be that some large organization will be formed, devoted to the prosecution of researches in volcanology in the United States or in the Pacific basin, which could take over the Kilauea Observatory, to the benefit of science. The desirability of such a transfer may be considered if and when a permanent organization of this kind is formed.

Under existing conditions it appears evident that hearty coöperation between all Governmental Bureaus conducting scientific work in Hawaii will be of great mutual benefit. The Committee ventures to refer directly to the mutual interest of the Weather Bureau and the National Parks Administration in making both Mauna Loa and Haleakala accessible, by constructing trails and shelter or camp accommodations, and in securing good topographic maps by the U. S. Geological Survey, of Kilauea and the two volcanoes just mentioned.

A geological survey of the whole Hawaiian group under either national or territorial auspices would be of great value to the volcanological work of the Weather Bureau. A well-considered coördination of the work of the Kilauea Observatory and of a geological survey should, of course, be made.

The Hawaiian Volcanic Research Association includes a number of generous, broad-minded men who retain an active interest in volcanological studies and it is in a position to take a helpful place in any coöperative scheme. Two other organizations in Honolulu, while not primarily interested in seismological and volcanological research, are devoting their resources largely to the promotion of science in the central Pacific region. One of these, the Bishop Museum, has expressed a desire, through its

Acting Director, to take part in any scientific undertaking which comes within the scope of its deed of trust, and the other, the University of Hawaii, possesses good laboratories and an increasingly strong scientific faculty.

The importance of world-wide correlation of plans for the advancement of the earth sciences has been referred to repeatedly in the course of this discussion. In closing it seems appropriate to call the attention of the Secretary of Agriculture to the developments now in progress aiming to secure the coöperation of agencies in many countries in promoting researches in meteorology, seismology, and volcanology, as well as in various sciences.

During the late war the National Academy of Sciences, at the request of President Wilson, organized the National Research Council to assist in coördinating and developing the research facilities of the United States, first as a measure of national defense and later as an aid in prosecuting the war. The success of this advisory and coöperative body has led to its perpetuation by the Academy, as directed by the President in an executive order of May 11, 1918.

The benefits of similar organization in other countries and of coöperation between the research agencies of different countries have been so fully recognized that an International Research Council has been formed by representatives of central bodies corresponding to the National Research Council, in several of the allied and associated countries.

One of the principal fields of effort for this International Research Council is to secure the formation under its auspices and with desirable unity and coördination of a number of international associations devoted to particular fields of science. These new organizations replace, in some instances, older ones whose operations were suspended during the war and cannot be revived to advantage under existing conditions.

Among these new bodies of international scope is the International Geophysical Union, devoted to a harmonious development of the earth sciences of physical aspect, dealing with many over-lapping problems. This Union has sections of (*a*) Geodesy; (*b*) Seismology; (*c*) Meteorology; (*d*) Terrestrial Magnetism and Electricity; (*e*) Physical Oceanography; (*f*) Volcanology. (A section of Geochemistry has been added since the submission of this Report.) As a part of the plan there will be organized in each country participating in the International Research Council a branch of the Union with sections corresponding to those named. Thus, in the United States, the American Geophysical Union has already been formed, in connection with the National Research Council. Professor Marvin is the Chairman of the Section of Meteorology. The membership of the various sections embraces a considerable number of leading investigators of the country in the special fields involved.

It is therefore possible at the present time to bring projects for the de-

velopment of seismologic and volcanologic research directly before both national and international bodies qualified to furnish advice and promote a broad coöperation of great value.

Yours respectfully,

WHITMAN CROSS, *Chairman*,
WILLIAM BOWIE,
ARTHUR L. DAY,
H. E. GREGORY,
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ERRATA

P. 215. For $v = \frac{9.\epsilon.E.D}{4\pi.\eta.l}$ read $v = \frac{q.\epsilon.E.D}{4\pi.\eta.l}$.

P. 268. In theorem II for "but $B_{\rho\lambda} \equiv 0$" read "but $B_{\rho\lambda}$ not $\equiv 0$"; and in theorem IV for "or $0 \overset{+}{+}$" read "or not $\equiv 0$".

P. 416. For the denominator of (1) read $2^a p^b$ where $a = \frac{1}{2} p^{n-1}(p-1)^2$, $b = \frac{1}{2} np^{n-2}(p-1)^2 - 1$, and on p. 417 read p^b for the denominator of the second fraction and 2^a for the left side of the next formula.

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